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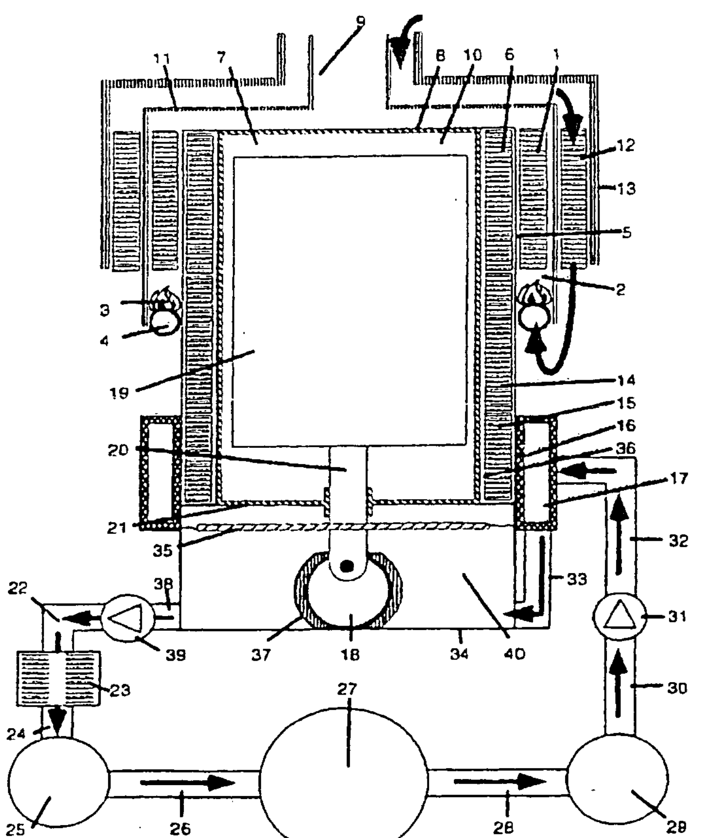
(54) Title: IMPROVED HEAT ENGINE WITH HYDRAULIC OUTPUT




**(57) Abstract:** A heat engine has a region within which a working fluid travels and an hydraulic fluid provided in a reservoir and the output from the heat engine drives the movement of the hydraulic fluid.



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– *with amended claims*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# Title: Improved Heat Engine with Hydraulic Output

## FIELD OF THE INVENTION

This invention relates to a new and improved linear hydraulic drive system for use with a Stirling engine.

## BACKGROUND PRIOR ART

Resonant free piston Stirling engine systems are known in the art wherein the load apparatus is hydraulically driven from the periodic pressure wave of the engine. In such known systems the load apparatus is typically disposed within an incompressible fluid-filled space between a pair of flexible diaphragms which seal in and isolate the incompressible fluid, referred to herein as "hydraulic fluid", from the Stirling Engine. One of the diaphragms is arranged to be acted on by the resulting pressure wave produced in the hydraulic oil and the other diaphragm is arranged as part of a gas spring. The pressure waves produced in the hydraulic oil are operative to reciprocally drive the movable member of the load apparatus in a direction along the same axis as that of the Stirling Engine. Such prior art engine-driven system assemblies were arranged in a stacked, coaxial relationship. While generally satisfactory, the diaphragms employed dramatically limited the useful life of such a device before maintenance was required. Other prior art arrangements had the load components immersed in the hydraulic oil making maintenance, service and repair difficult and expensive.

## SUMMARY OF THE INVENTION

The hydraulic drive system of the instant invention is arranged and constructed to operate from the periodic pressure wave of the Stirling engine to pump the hydraulic fluid through a loop wherein a piston or motor drive is deployed to covert the hydraulic fluid flow to linear or rotary motion. In one embodiment, the hydraulic fluid is acted upon directly by the periodic pressure wave produced by the Stirling

Engine. Alternately, the heat engine or Stirling engine may produce mechanical or electrical power that is used to power the hydraulic output system.

While the new and improved hydraulic power output and pump system of this invention is capable of use with a Stirling engine, it can be equally well applied in systems wherein fuel explosions or other periodic pressure pulses are available to provide the motive force. Also, while the invention will generally be described in connection with a hydraulic motor, it is understood that the invention could also be applied to compressors, pumps, pistons, linear alternators, and other like load apparatus.

In accordance with the instant invention, there is provided a new and improved hydraulic drive system for use with a Stirling engine which reduces the length of the engine-drive assembly.

In accordance with the instant invention, there is also provided a hydraulic drive system for use with a Stirling engine wherein the hydraulic oil is positively displaced so as to provide compact, light-weight drive means consisting of few components which can directly provide power to conventional pistons, hydraulic motors, or other like loads.

In accordance with the instant invention, there is also provided a hydraulic drive system for use with a Stirling engine which can be readily pressurized to 100 atm for use with a Stirling engine similarly pressurized so as to provide a very high specific power per unit weight and per unit volume in a compact, light-weight drive means.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other advantages of the instant invention will be more fully and particularly understood in connection with the following description of the preferred embodiments of the invention in which:

Figure 1 is a cross section of a heat engine and a hydraulic drive system according to the instant invention;

Figure 2 is a three dimension sketch of a hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the pump employs a tangential inflow and a tangential outflow design;

Figure 3 is a three dimension sketch of a hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the pump employs a tangential inflow and bottom outflow design;

Figure 4 is a three dimension sketch of a hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the pump employs a bottom inlet through a three dimension elbow and a tangential outflow design; and,

Figure 5 is a schematic drawing of an alternate embosiment of a heat engine and a hydraulic drive system according to the instant invention

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the invention is shown in Figure 1. A shroud 11 covers a series of louvred fins 1 which transfer heat from the hot combustion gasses 2 to the heat engine wall 5 and into the louvred fins 6 within the engine which in turn transfer the heat to the working fluid 7. In addition, the hot combustion gasses 2 transfer heat to the upper end-cap 8 which in turn transfers this heat to the working fluid 7 within the engine. The hot combustion gasses are produced by the flame 3 which is fed by the gas ring burner 4. The hot combustion gasses exit the system through the chimney 9. In addition, radiation transfers heat from the flame 3 to the louvred fins 1. The shroud 11 is supported by a series of louvred fins 12 which are in turn supported by an outer cover 13. The louvred fins 12 act as

a pre-heater for the combustion gasses thereby improving the burner efficiency and also act to support the heated section of the heat engine wall 5 which is weakened due to its heating. The outer cover 13 is substantially colder than the heat engine wall 5 and the louvred fins 12 and 1 serve to mechanically translate the support offered by the outer cover 13 to the heat engine wall 5. Thus, a cooler metal serves to support the hotter wall. The louvred fins 14 serve as the regenerator section of the heat engine while the louvred fins 15 serve to remove heat from the working fluid and transfer it through the cold section of the heat engine wall 16 and into the hydraulic fluid 40. It will be appreciated that other construction for a heat engine may be used with the hydraulic drive described hereafter.

The displacer 19 is supported by a shaft 20 which is supported by member 21 and is attached to an eccentric drive 18 which is mounted on an electric motor 37 which is immersed in the hydraulic fluid 40 within the main pump chamber 34 whereby eliminating the need for a pressure seal within the displacer drive system.

When the engine is hot and the displacer 19 moves to its bottom dead centre position the working fluid 7 expands thereby exerting pressure on the hydraulic fluid 40 within the main pump chamber 34. The hydraulic fluid 40 begins to flow in response to this pressure. The hydraulic fluid 40 flows through the pipe 38 through the one way check valve 39 through pipe 22 through the heat exchanger 23 through pipe 24 into accumulator 25 through pipe 26 and through the motor 27 (which provides useful work - i.e. the output to a load) through pipe 28 into accumulator 29 through pipe 30 through check valve 31 through pipe 32 through the cooling section 17 and through pipe 33 back into the main pump chamber 34.

The accumulator 29 maintains a pressure greater than the engine buffer pressure so that when the displacer travels to the top dead centre and the pressure within the engine is reduced to the buffer

pressure, the hydraulic fluid 20 can flow through pipe 30 through check valve 31 through pipe 32 through the cooling section 17 and through pipe 33 back into the main pump chamber 34 to refill the main pump chamber 34 in preparation for the next cycle. The size of the reservoirs 25 and 29 and of the entire hydraulic piping must be sufficient to allow the rate of flow required to deliver the power output from the engine to the motor 27. One major advantage of this system is that the accumulators 25 and 29 and the working fluid 7 can all be pre-pressurized to a high pressure thereby yielding a very high specific power output for a small engine. The hydraulic fluid may be an oil or an aqueous fluid. If the hydraulic fluid is an oil, then the preferred hydraulic oil is silicone oil. If the hydraulic fluid is aqueous, then the preferred hydraulic fluid comprises water, an antifreeze and a corrosion inhibitor. In some applications, the aqueous hydraulic fluid may be buffered.

Optional floating splash guard 35 minimizes splash within the engine. The member 21 also serves to trap a small amount of gas in a head space above the hydraulic fluid thereby ensuring that the fluid level can never rise above member 21. Alternatively, a float mechanism may be employed to limit the amount of hydraulic fluid which will flow in during the refilling cycle although the buffer pressure should control this as well.

An embodiment for the hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the hydraulic pump employs a tangential inflow and a tangential outflow design is shown in Figure 2. In this embodiment the fluid to be pumped 40 enters the pump housing 45 through tangential inlet 41 and follows a spiral path 42 to the tangential outlet 43 where the fluid 44 exits the pump. A check valve (not shown) may be used at one or both of the inlet 41 and the outlet 44 to maintain unidirectional flow within the pump.

An embodiment for the hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the hydraulic pump employs a tangential inflow and an axial outflow design is shown in Figure 3. In this embodiment the fluid to be pumped 46 enters the pump housing 51 through tangential inlet 47 and follows a spiral path 48 to the bottom outlet 49 where the fluid 50 exits the pump. A check valve (not shown) may be used at one or both of the inlet 47 and the outlet 49 to maintain unidirectional flow within the pump.

An embodiment for the hydraulic pump to be driven by a periodic pressure pulse source such as a Stirling engine wherein the hydraulic pump employs an axial inflow and a tangential outflow design is shown in Figure 4. In this embodiment the fluid to be pumped 52 enters the pump housing 58 through a bottom inlet 53 and through a three dimensional elbow 54 which sets the flow onto a spiral path 55 to the tangential outlet 56 where the fluid 57 exits the pump. A check valve (not shown) may be used at one or both of the inlet 53 and the outlet 56 to maintain unidirectional flow within the pump.

In the alternate embodiment of Figure 5, a hydraulic power deliver system utilizes mechanical energy output from a heat engine. As shown therein, a heat engine 60, which may the same or different to the heat engine shown in Figure 1, has a linear to rotary converter. Linear to a rotary converter may be provided integrally with heat engine 60. For example, as shown in Figure 5, linear to rotary converter is designated by reference numeral 62 and is enclosed in container 64 which may be the outer shell of heat engine 60. Mechanical energy from linear to rotary converter 62 is supplied by output shaft 66 which is drivingly connected to pump 68. Output shaft may be directly drivingly coupled to pump 68 or, alternately, it may be indirectly coupled such as through a transmission or other power

regulation means. In a further alternate embodiment, heat engine 60 may include a linear generator (e.g. the power piston of heat engine 60 may comprise a portion of a linear generator). In such a case, heat engine 60 would produce electricity which could be used to power pump 68.

**I Claim:**

1. A heat engine having a region within which a working fluid travels and an output system including hydraulic fluid which is provided in a reservoir whereby the heat engine produces power which is used to pump the hydraulic fluid.

2. The heat engine as claimed in claim 1 wherein the reservoir is open to the region within which a working fluid travels whereby the working fluid directly contacts the hydraulic fluid to pump the hydraulic fluid.

3. The heat engine as claimed in claim 1 wherein the hydraulic fluid is silicone oil.

4. The heat engine as claimed in claim 1 wherein the flow of hydraulic fluid into and out from the reservoir is tangential.

5. The heat engine as claimed in claim 1 wherein the flow of hydraulic fluid into the reservoir is tangential and the flow of hydraulic fluid out from the reservoir is axial.

6. The heat engine as claimed in claim 1 wherein the flow of hydraulic fluid into the reservoir is axial and the flow of hydraulic fluid out from the reservoir is tangential.

7. The heat engine as claimed in claim 1 wherein the working fluid and the hydraulic fluid are each pressurized to a pressure above atmospheric pressure.

8. The heat engine as claimed in claim 1 wherein the working fluid and the hydraulic fluid are each pressurized which is greater than atmospheric pressure.

9. The heat engine as claimed in claim 1 wherein the hydraulic fluid travels through a circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor.

10. The heat engine as claimed in claim 9 wherein the fluid driven motor has a rotary output.

11. The heat engine as claimed in claim 10 wherein the accumulators and the fluid driven motor are integrated into a single housing to thereby provide a rotary output system which employs fluid seals and does not require gas seals.

12. The heat engine as claimed in claim 1 wherein the sealed region has a heating chamber and a cooling chamber and the hydraulic fluid travels through a circuit that includes a heat exchange portion exterior to the cooling chamber whereby the hydraulic fluid is employed to remove heat from the cooling chamber.

13. The heat engine as claimed in claim 12 wherein the circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor and the heat exchange portion is part of a single flow line.

14. The heat engine as claimed in claim 1 wherein the hydraulic fluid travels through a circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor and a

radiator is provided in the circuit to remove excess heat from the engine.

15. The heat engine as claimed in claim 14 wherein the radiator is positioned downstream of the reservoir

16. A heat engine having a region within which a working fluid travels and a heat source, the region has a heating chamber and a cooling chamber, the heat source is thermally connected to the heating chamber, and louvred fins are positioned in the heating chamber whereby the louvred fins transfer heat from the heat source to the working fluid as the working fluid travels through the louvred fins.

17. A heat engine having a region within which a working fluid travels and a combustion chamber, the region has a heating chamber and a cooling chamber and an outer wall, the combustion chamber is thermally connected to the heating chamber, and a heat exchanger provided exterior to a portion of the outer wall, the heat exchanger having first and second annular fluid flow passageways, each passageway has an outer wall secured in place by mechanical engagement by a plurality of spaced apart fins that extend across the respective fluid flow passageway.

18. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of hydraulic fluid into the reservoir is axial and the flow of hydraulic fluid out from the reservoir is tangential.

19. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of hydraulic fluid into and out from the reservoir is tangential.

20. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of hydraulic fluid into the reservoir is tangential and the flow of hydraulic fluid out from the reservoir is axial.

[Received by the Internationnal Bureau on 18 July 2002 (18.07.2002)
original claims 1-20 replaced by amended claims 1-20

I Claim:

1. A heat engine having a region within which a working fluid travels and an output system including a chamber having a liquid inlet and a liquid outlet, whereby the heat engine produces power which is used to sequentially draw liquid into the inlet to the chamber and to then pump the liquid out of the outlet.

2. The heat engine as claimed in claim 1 wherein the chamber is open to the region within which a working fluid travels whereby the working fluid directly contacts the liquid to pump the liquid.

3. The heat engine as claimed in claim 1 wherein the liquid is silicone oil.

4. The heat engine as claimed in claim 1 wherein the flow of liquid into and out from the reservoir is tangential.

5. The heat engine as claimed in claim 1 wherein the chamber is a liquid reservoir and the flow of liquid into the reservoir is tangential and the flow of liquid out from the reservoir is axial.

6. The heat engine as claimed in claim 1 wherein the chamber is a liquid reservoir and the flow of liquid into the reservoir is axial and the flow of liquid out from the reservoir is tangential.

7. The heat engine as claimed in claim 1 wherein the chamber is a liquid reservoir, the liquid travels in a circuit and the working fluid and the liquid are each pressurized to a pressure above atmospheric pressure.

8. The heat engine as claimed in claim 1 wherein the chamber is a liquid reservoir, the liquid travels in a circuit and the working fluid and the liquid are each pressurized which is greater than atmospheric pressure.

9. The heat engine as claimed in claim 1 wherein the liquid travels through a circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor.

10. The heat engine as claimed in claim 9 wherein the fluid driven motor has a rotary output.

11. The heat engine as claimed in claim 10 wherein the accumulators and the fluid driven motor are integrated into a single housing to thereby provide a rotary output system which employs fluid seals and does not require gas seals.

12. The heat engine as claimed in claim 1 wherein the sealed region has a heating chamber and a cooling chamber and the liquid travels through a circuit that includes a heat exchange portion exterior to the cooling chamber whereby the liquid is employed to remove heat from the cooling chamber.

13. The heat engine as claimed in claim 12 wherein the circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor and the heat exchange portion is part of a single flow line.

14. The heat engine as claimed in claim 1 wherein the liquid travels through a circuit that includes an accumulator positioned upstream and downstream from a fluid driven motor and a radiator is provided in the circuit to remove excess heat from the engine.

15. The heat engine as claimed in claim 14 wherein the radiator is positioned downstream of the reservoir

16. A heat engine having a region within which a working fluid travels and a heat source, the region has a heating chamber and a cooling chamber, the heat source is thermally connected to the heating chamber, and louvred fins are positioned in the heating chamber whereby the louvred

fins transfer heat from the heat source to the working fluid as the working fluid travels through the louvred fins.

17. A heat engine having a region within which a working fluid travels and a combustion chamber, the region has a heating chamber and a cooling chamber and an outer wall, the combustion chamber is thermally connected to the heating chamber, and a heat exchanger provided exterior to a portion of the outer wall, the heat exchanger having first and second annular fluid flow passageways, each passageway has an outer wall secured in place by mechanical engagement by a plurality of spaced apart fins that extend across the respective fluid flow passageway.

18. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of fluid into the reservoir is axial and the flow of fluid out from the reservoir is tangential.

19. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of fluid into and out from the reservoir is tangential.

20. An hydraulic pump in fluid flow communication with a heat engine to be driven by a periodic pulse produced by the heat engine wherein the fluid travels through a path that includes a reservoir and the flow of hydraulic fluid into the reservoir is tangential and the flow of hydraulic fluid out from the reservoir is axial.

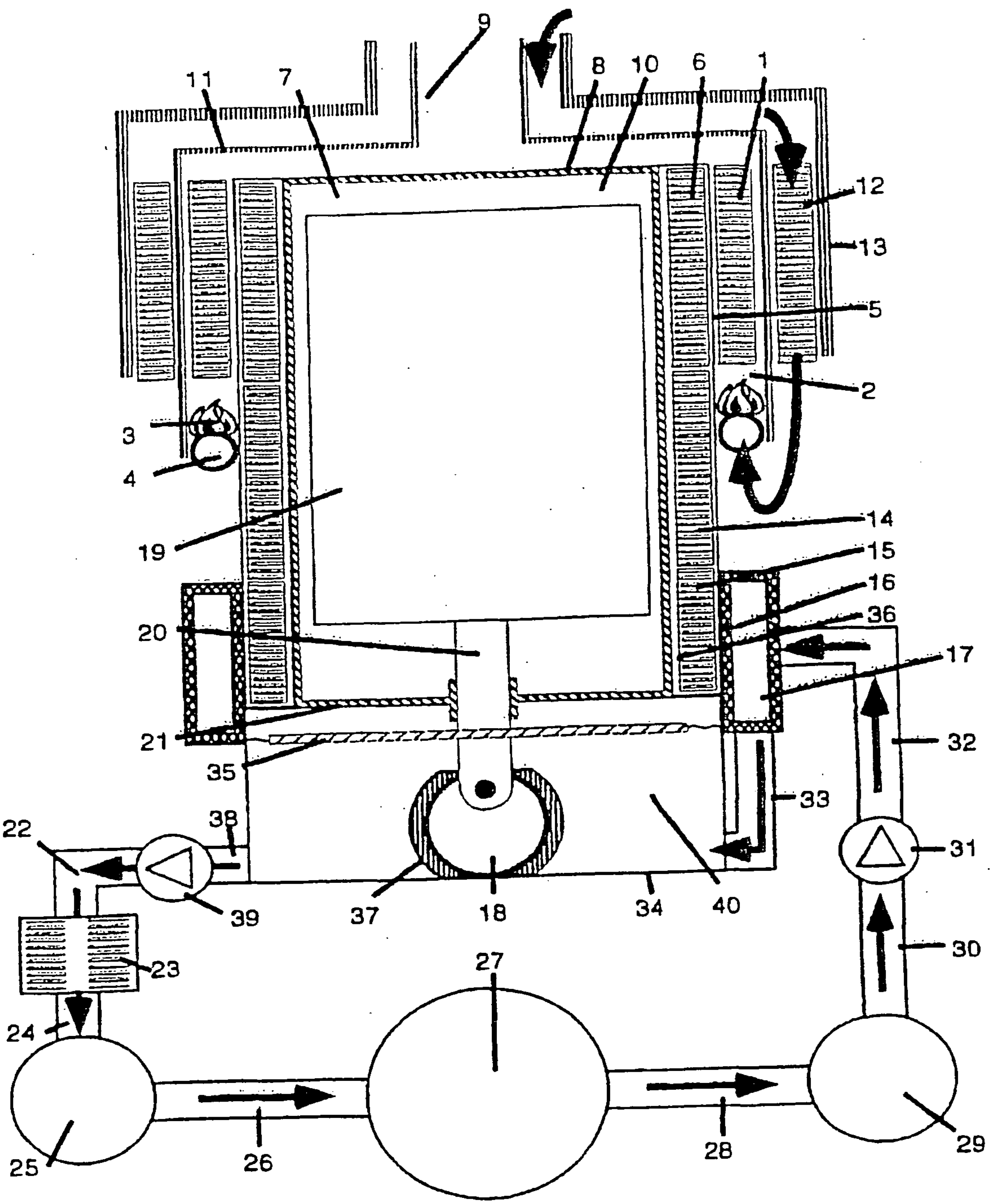
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Figure 1

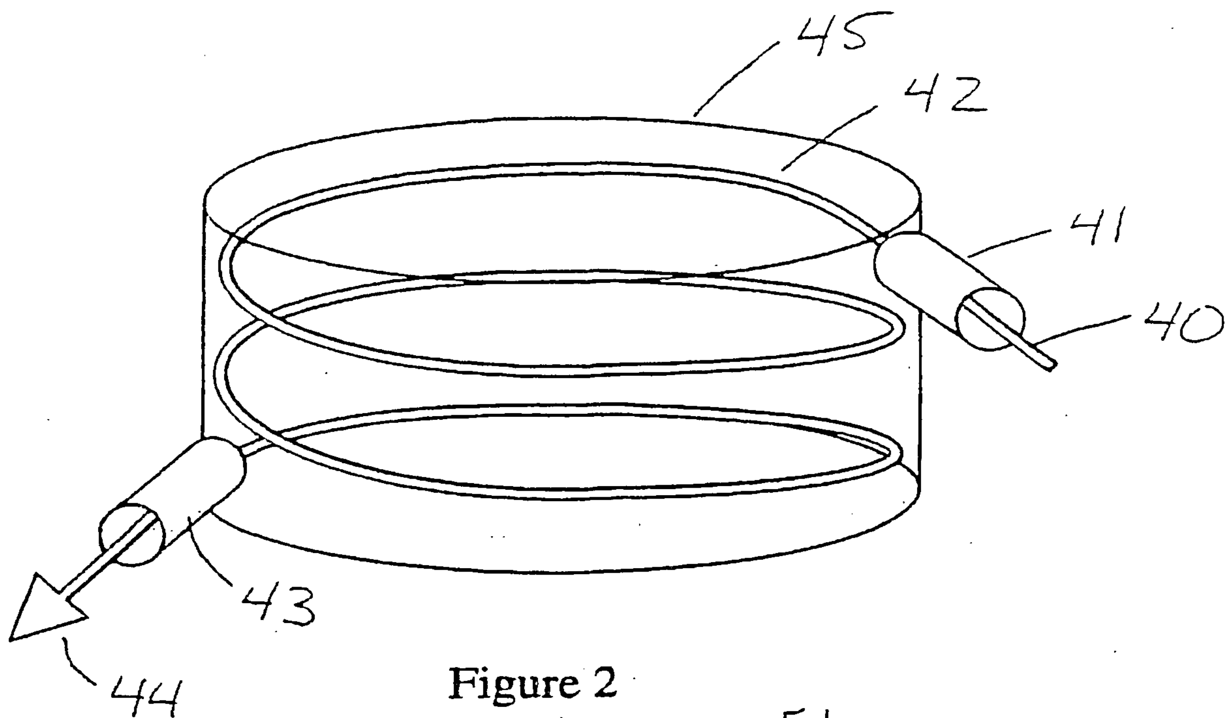


Figure 2

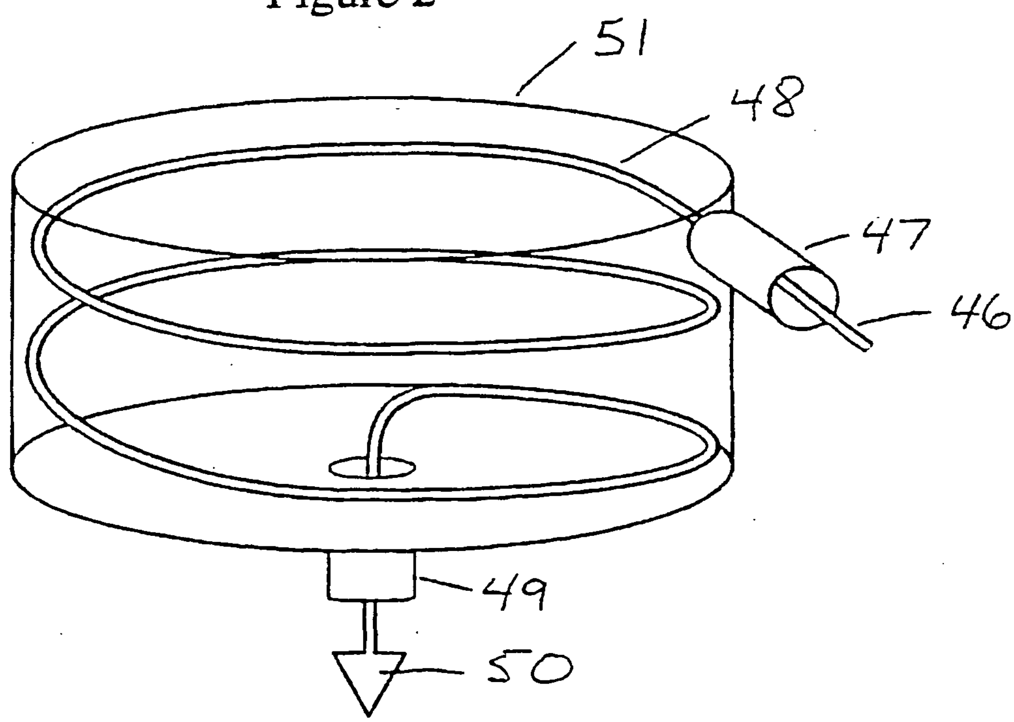


Figure 3

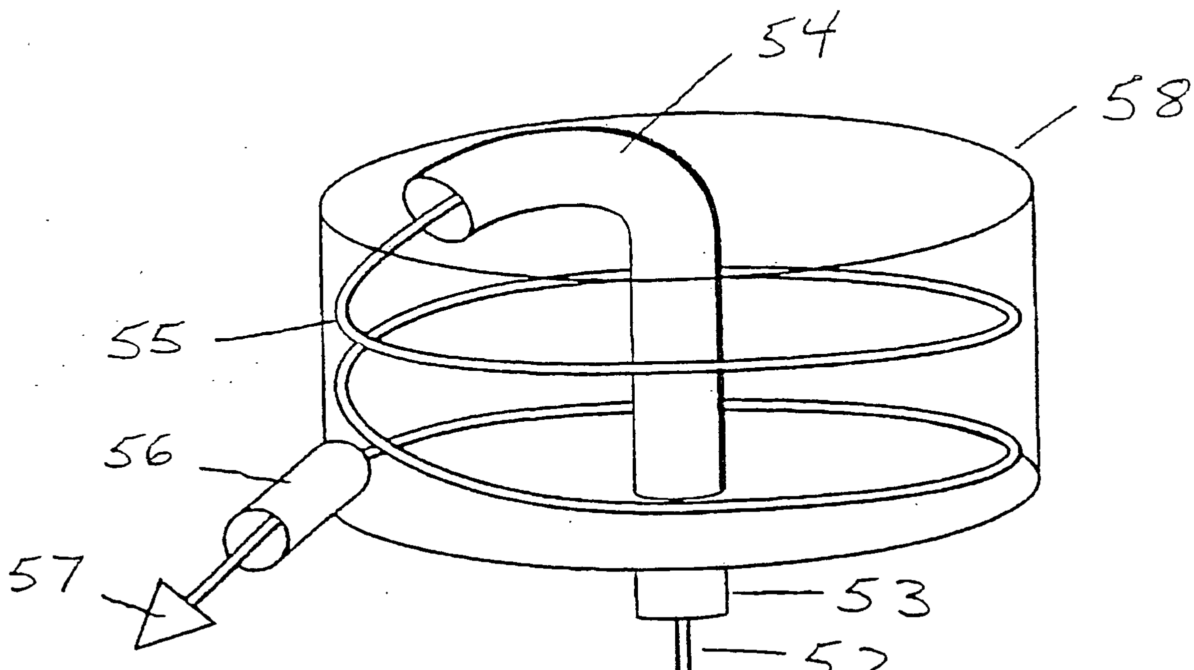


Figure 4

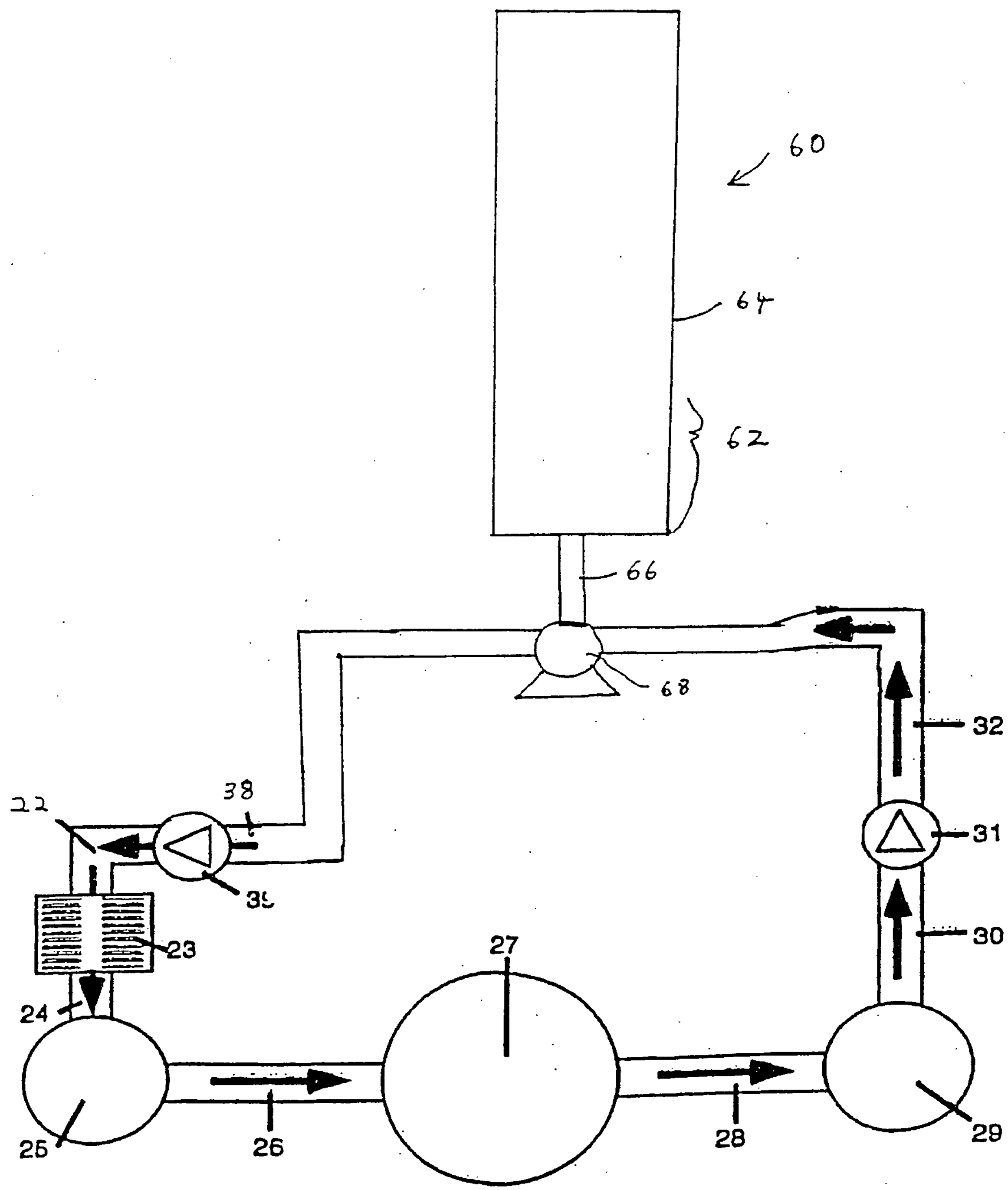


Figure 5

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 02/00290

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F02G1/043

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F02G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
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| 17 June 2002 | 24/06/2002 |

| Name and mailing address of the ISA | Authorized officer |
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| European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016 | Wassenaar, G |

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